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LOGISTIC EFFICIENCY THROUGH HORIZONTAL COOPERATION: THE CASE OF FLEMISH ROAD TRANSPORTATION COMPANIES

By Frans Cruijssen, Wout Dullaert, Tarja Joro

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Logistics efficiency through horizontal cooperation: The case of Flemish road transportation companies

Frans Cruijssen[a,b], Wout Dullaert[c], Tarja Joro[d]

[a] Tilburg University, Faculty of Economics and Business Administration, Tilburg, the Netherlands
[b]TNO Mobility and Logistics, Delft, the Netherlands
[c]University of Antwerp, Institute of Transport and Maritime Management Antwerp, Belgium
[d]Department of Finance and Management Science, University of Alberta School of Business, Edmonton, Alberta, Canada

Abstract
This paper describes a practical application of Data Envelopment Analysis (DEA) to the Flemish road transportation sector. The efficiency of 82 road transportation companies responding to a large-scale survey focused on horizontal cooperation is evaluated, based on two inputs and two outputs. Various DEA models are used to identify differences between subgroups of respondents. The results demonstrate that, in general, Flemish road transportation companies operate at unacceptably low efficiency levels. Given the findings that the median company is operating on too small a scale one apparent remedy would be a dramatic increase in market concentration through mergers and acquisitions.

Keywords: Horizontal Cooperation; Road transportation companies; Data Envelopment Analysis
*JEL codes:*C44, L92

European Road Transportation Companies (RTCs) are facing hard times. Low capacity utilization, significant amounts of empty haulage (although this is not applicable to some markets, e.g. packed goods), declining profit margins, and a negative public image have become symptomatic of the sector as a whole. The main causes for these problems are the fierce competition in the globalizing markets, high fixed costs, rising petrol and labour prices, the proliferation of products with shorter life cycles and the ever-increasing expectations of customers in terms of both service and price (cf. Verstrepen et al. 2006). This has caused a strong fragmentation of transportation flows, which in turn has led to severe adverse effects on RTCs' business and profitability. As an illustration of these difficult market conditions, Eurostat (2006) figures show that after an increase in the 1990s, the number of active RTCs has steadily been declining over the last five years in the three largest European economies (see Figure 1).

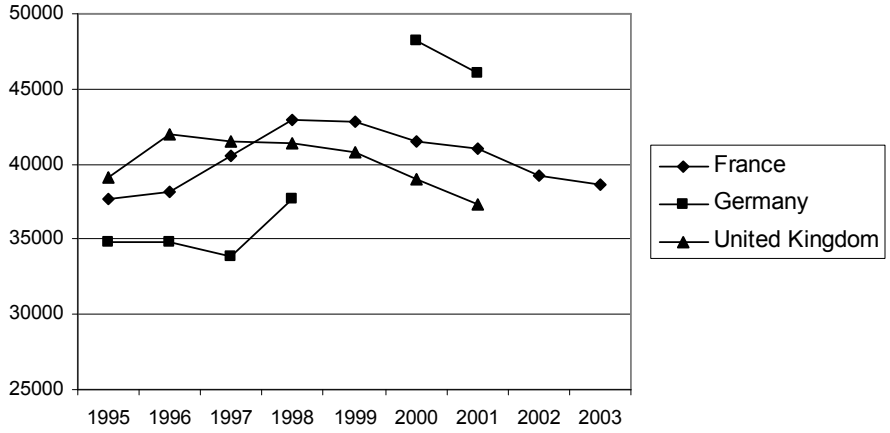

Figure 1. Number of RTCs (source: Eurostat, 2006)

Understanding the performance of companies active in the road transportation sector and gaining greater insight into the characteristics of those transporters with poor or excellent performance is critical for the long-term competitiveness of the whole sector. This paper is aimed to increase this understanding, and more specifically focuses on one possible way of improving efficiency and profitability: horizontal cooperation. The European union (2001) defines horizontal cooperation as "concerted practices between companies operating at the same level(s) in the market". In the road transportation sector in particular there are almost no unique technologies, and companies must often rely on applying innovative organizational concepts such as horizontal cooperation to achieve profit or growth. Except for a small number of successful cases in North America, the concept of horizontal cooperation in (road) transportation is mainly gaining momentum in Western Europe. In Belgium and the Netherlands, the European logistics centres of gravity, the authors are aware of over 40 publicized partnerships.

In this paper we use Data Envelopment Analysis (DEA) to test a number of conjectures on efficiency in road transportation, based on a large-scale survey undertaken at RTCs in Flanders (Belgium). The remainder of this paper is organized as follows. Section 1 introduces the conjectures and their rationale. Then in Section 2 we discuss the setup of the survey in Flanders and provide brief results. Consequently in Section 3 the use of DEA in our research is explained, and the results of the DEA are provided in Section 4, together with the testing of the conjectures. Finally, Section 5 draws the conclusions of this research.

1. Research questions

The first two conjectures relate to the scale at which RTCs operate. It is readily accepted that from an operational point of view, RTCs benefit from a certain level of scale that enables them to construct efficient (round)trips, reduce inter-drop distances and/or reduce empty mileage. On the other hand, when companies grow too large, coordination costs may increase disproportionately. This would imply the existence of an 'optimal' size for RTCs. We hypothesize that in Flanders the sector is too fragmented, i.e. that many RTCs are operating below their respective optimal size. In 2003 for example, the number of RTCs in Flanders equalled 4 667. With a population of around 6 million people, this means that there is one RTC per 1 285 inhabitants. To gain insight into the optimal firm size we formulate and test the following two related conjectures:

- *C1: Larger companies in Flanders are more efficient*
- *C2: The Belgian transportation market is too fragmented.*

Secondly, we are interested in apparent relations between the characteristics, efficiency levels and horizontal cooperation of a firm. Horizontal cooperation is considered a means to improve efficiency of logistics companies such as RTCs (cf. Bahrami, 2003; Vos et al., 2003; Groothedde, 2005). This leads us to expect that RTCs which are in fact engaged in a horizontal partnership perform better on average than companies that are not. However, successfully implementing and managing horizontal partnerships is not easy (cf. Verstrepen et al., 2006). A considerable amount of vision, market knowledge, and professionalism is required before a company finds a workable means of cooperating horizontally with companies that are potential competitors. We therefore anticipate that highly inefficient companies have enough trouble managing their own business, and will be less inclined to start up a horizontal cooperation than their more efficient counterparts. Furthermore, we are interested in knowing whether there is a link between the scale of an RTC and horizontal cooperation. This boils down to the following three conjectures:

- *C3: Cooperating companies show greater efficiency levels than non-cooperating companies.*
- *C4: Companies interested in (intensified) cooperation are more efficient than companies that are not interested.*
- *C5: Larger companies cooperate more often than smaller ones*.

Finally, we want to know if the efficiency level of firms has an impact on their attitude towards opportunities of or impediments for horizontal cooperation. If statistically significant relationships are proven, these relationships, together with the result of conjecture C4, can tell us if horizontal cooperation is primarily a 'defensive' strategy to solve inefficiency problems, or a more 'proactive' strategy to protect the satisfactory current efficiency level of an RTC. To test this, we use the following two conjectures.

- *C6: Less efficient companies value the opportunities of cooperation higher than more efficient companies do.*
- *C7: Inefficient companies consider the impediments for horizontal cooperation to be more severe than less efficient firms do.*

2. The Survey

This study builds upon the results of a large-scale survey on horizontal cooperation. In this section we briefly describe the sampling procedure, respondents and results of the survey[1]. In order to test the attitudes of Flemish Logistics Service Providers (LSPs) towards horizontal cooperation, a personalized questionnaire was sent on March 17th 2003 to 1537 Flemish LSPs, completed forms returning in the period from March 19th until April 14th 2003. In total, 154 useful copies were received. In addition, eleven in-depth interviews were conducted to crosscheck and fine-tune the findings from the analysis of the questionnaires.

2.1 Sample selection and respondents

The LSPs in the sample were selected from BelFirst (BelFirst, 2003), a database containing the annual accounts of over 250,000 companies in Belgium. The survey included LSPs with the following main activity codes: 60242 (Freight transportation by road), 612 (Inland water transportation), 631 (Cargo handling and storage), 63401 (Courier activities other than national post activities) and 6412 (Freight forwarding).

With a few exceptions[2], all Belgian companies are obliged to publish their annual accounts. Whereas large companies must submit a 'complete' annual account, small and medium-sized companies are permitted to submit a short or 'contracted' annual account. The definition of "large" is a company which either on average employs more than 100 people during a specific year or if one of the following three criteria is exceeded:

- Average number of employees of 50
- Annual turnover (excluding Value Added Tax) of € 7 300 000.
- Value of total assets of € 3 650 000

The selection of the sample was based on the annual accounts of 2002, which was the most recent year for which all reports had been submitted at the time of the survey.

The sample structure was such that 25% of the questionnaires were sent to large companies and 75% to small or medium-sized enterprises (SMEs). This ensured a sufficient representation of the larger companies in view of their economic importance and at the same time offered the possibility to thoroughly survey small and medium-sized LSPs which strongly outnumber the large companies in the Flemish road transportation sector. In this way, 1537 LSPs were selected: 390 of the larger ones and 1148 SMEs. Table 1 summarizes the setup of the sample. For each cell in the table, the first number refers to the number of companies contained in the sample, and the second to the number of companies in the Belfirst database. The last column displays the number of respondents for each LSP category.

[1] For a more detailed description refer to Cruijssen et al. (in press).

[2] For details about which companies are not obliged to file an annual account, see the National Bank of Belgium website (www.nbb.be).

Table 1
Sample composition according to NaceBel main activity codes and the number of employees in FTEs

NaceBel main activity	0-4	5-19	20-49	50-99	100+	Total	Respondents
Freight transportation by road	606 (2258)	261 (888)	132 (374)	40 (79)	21 (37)	*1060 (3636)*	*118*
Water transportation, inland navigation	40 (126)	9 (10)	3 (3)	0 (0)	0 (0)	*52 (139)*	*6*
Cargo handling and storage	92 (286)	55 (142)	29 (51)	15 (25)	12 (19)	*203 (523)*	*15*
Forwarding offices	58 (187)	34 (92)	27 (44)	14 (15)	10 (12)	*143 (350)*	*7*
Express	61 (232)	10 (18)	6 (6)	0 (0)	2 (2)	*79 (258)*	*8*

Because the sample contained five different types of companies that are generally active in disjunctive markets, it is not possible to objectively compare their efficiency levels. We therefore focus on one category: freight transportation by road. With a market share of 75% of the total freight transport volume (Eurostat, 2006), this transportation mode is dominant in Flanders. Restricting the analysis to road freight transport respondents reduces the size of the sample to 118.

To calculate company efficiency levels data on their input and output levels are needed. Due to the fact that information on inputs and output levels are considered confidential by many LSPs, we feared that including these questions would significantly reduce the response rate. We therefore collected information on total assets and total hours worked (inputs) and added value and profit or loss (outputs) from the Belfirst database. Since the companies completed the questionnaires in 2003, the input/output data of that year is used. Of the 118 responding RTCs however, seven appearing in the 2002 edition did not appear in the Belfirst database of 2003, meaning that they terminated their activities in the period between the survey date and the end of 2003. These seven companies have been removed from the sample, resulting in a set of 111 companies for which we have the required financial data. Unfortunately, the smallest companies are not obliged by Belgian law to submit a social balance sheet. Since the data on labour input come from these social balance sheets, these companies also have to be removed from our set. After removing these very small companies we are left with a group of 83 companies that have filed all relevant input data. One extra firm was removed because the total hours worked in that company amounted to only 152 for 2003, which was considered too few for a normally operating company. The next smallest number of hours worked was 1501, which is close to 1 FTE, so all other responding companies in the set are retained. The final analysis set therefore consists of 82 companies.

2.2 Short survey results

In this section we provide a summary of the results of the survey that are relevant to the current paper. More specifically, in order to test conjectures C6 and C7 the respondents' attitudes towards opportunities of and impediments for horizontal cooperation are required. To capture these attitudes we use the respondents' evaluations of two sets of propositions on opportunities and impediments that were incorporated in the questionnaire. Respondents were asked to rate these propositions on a five-point Likert scale, encompassing the following choices: "Strongly agree" (5), "Agree" (4), "Neutral" (3), "Disagree" (2), and "Strongly disagree" (1).

Table 2
Propositions regarding opportunities and impediments

Code	Proposition
Opportunities	
O1	Horizontal cooperation increases the company's productivity for core activities, e.g.: decrease in empty hauling, better usage of storage facilities etc.
O2	Horizontal cooperation reduces the costs of non-core activities, e.g.: organizing safety trainings, joint fuel facilities etc.
O3	Partnerships reduce purchasing costs, e.g.: vehicles, onboard computers, fuel etc.
O4	LSPs can specialize, while at the same time broadening their services.
O5	LSPs can offer better quality of service at lower costs, e.g. in terms of speed, frequency of deliveries, geographical coverage, reliability of delivery times etc.
O6	Tendering on larger contracts with large shippers becomes possible.
O7	Forming partnerships helps to protect market share.
Impediments	
I1	It is hard to find commensurable LSPs with which it is possible to cooperate for (non-) core activities.
I2	It is hard to find a reliable party that can coordinate the cooperation in such a way that all participants are satisfied.
I3	It is hard to determine the benefits or operational savings due to horizontal cooperation beforehand.
I4	Partners find it hard to ensure a fair allocation of the shared workload in advance.
I5	A fair allocation of the benefits is essential for a successful cooperation.
I6	When an LSP cooperates with commensurable companies, it becomes harder for it to distinguish itself.
I7	Over time smaller companies in the partnership may lose clients or get pushed out of the market completely.
I8	Benefits cannot be shared in a fair way; the larger players will always benefit most.
I9	Cooperation is greatly hampered by the required indispensable ICT-investments.

Table 3 indicates that both the impediments and the opportunities of horizontal cooperation are endorsed quite strongly. The most supported opportunity of cooperation is the possible increase in a company's productivity in its core activities (O1). 79% of the respondents to the survey agreed with this proposition, while only 2% disagreed. The in-depth interviews revealed that decreases in empty mileage, better usage of storage facilities and increased load factors are the most common examples. The impediments for cooperation that the respondents consider most prohibitive is the problem of finding a reliable party that can coordinate the cooperation in such a way that all participants are satisfied (I2) and the construction of fair allocation mechanisms for the attained savings (I5).

Table 3
Summary of evaluations of the propositions

Code	Mean	Standard deviation	#observ.	Missing	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Opportunities									
O1	4.26	0.83	77	5	1	1	10	30	35
O2	3.68	0.92	77	5	1	4	31	24	17
O3	3.30	1.04	77	5	3	11	36	14	13
O4	3.71	1.05	77	5	4	4	20	31	18
O5	3.55	1.02	76	6	5	1	31	25	14
O6	3.57	1.16	77	5	4	9	24	19	21
O7	3.29	1.06	77	5	3	14	30	18	12
Total	3.62	1.06							
Impediments									
I1	3.92	0.97	79	3	1	6	16	31	25
I2	4.05	0.83	79	3	0	3	16	34	26
I3	3.54	0.89	78	4	0	11	24	33	10
I4	3.72	0.88	78	4	2	5	17	43	11
I5	4.10	0.86	78	4	1	2	13	34	28
I6	3.57	0.85	77	5	0	10	21	38	8
I7	3.97	0.94	78	4	0	6	17	28	27
I8	3.59	1.17	78	4	3	13	18	23	21
I9	3.48	0.87	77	5	0	8	35	23	11
Total	3.77	0.95							

2.3 Categorizations

To support the analysis of the conjectures formulated in the introduction, we introduce 3 categorizations of respondents, which are explained in Table 4.

Table 4
Categorizations of respondents

Categorization	Explanation
Cooperator & Non-cooperator	A respondent is indicated to be a cooperator if he/she regards him/herself as currently cooperating horizontally on either core or non-core activities (questionnaire result).
Interested & Not-interested	Companies are those who answered positively to the question "In the current situation, are you interested in (intensifying) horizontal cooperation with sister companies" are referred to as interested firms, those who negated are the not interested firms (questionnaire result).
Complete account & Contracted account	The categorization is based on the type of annual account that a company has to submit (result form Belfirst database).

When the results in Table 3 are reorganized into the described categorization, the numbers in Table 5 are produced. The null hypotheses state that there is no difference between the evaluations of different subgroups. In the top-left corner of Table 5 for example, the null hypothesis is: "Cooperators and Non cooperators value the opportunities of horizontal cooperation alike". It turns out that Cooperators agree with the opportunities of horizontal cooperation more than non-cooperators do. Similarly, the cooperators consider the impediments for horizontal cooperation to be less severe than the non-cooperators do. Both observations also hold true for the interested vs. the not interested companies. Finally, the companies with

a contracted annual account consider the impediments for horizontal cooperation to be more severe than the companies with a complete annual account.

Table 5
Breakdown of results according to categorizations

	Opportunities				Impediments			
	Average	**Standard deviation**	**Mann-Whitney**	**Asymp. Sig.**	**Average**	**Standard deviation**	**Mann-Whitney**	**Asymp. Sig.**
Cooperator	3.77	1.09	30264.5	0.002	3.65	0.96	52748	0.005
Non-cooperator	3.51	1.02			3.86	0.93		
Interested	4.04	1.05	21011	0.000	3.6	1.06	52230	0.001
Not interested	3.31	0.95			3.9	0.82		
Contracted account	3.6	1.06	27811	0.547	3.84	0.9	41465	0.009
Complete account	3.69	1.05			3.59	1.04		

3. The use of Data Envelopment Analysis

The conjectures listed in the introduction assume knowledge about the efficiency of RTCs. However, this efficiency is not directly measurable, but rather depends on the levels of multiple outputs, relative to used levels of multiple inputs. In cases where a set of Decision Making Units (in our case these are RTCs) perform similar tasks under multiple inputs and multiple outputs, DEA is considered an appropriate technique to measure efficiency.

DEA was developed by Charnes et al. (1978) who followed work of Farrell (1957). It allows the measurement of the efficiency of firms by benchmarking them with respect to an estimated piece-wise linear production function. This model is known as the CCR model, after its inventors. Banker et al. (1984) further built upon the CCR model to arrive at the BCC model. Whereas the CCR model explicitly assumes that companies are operating at their most efficient scale by imposing constant returns to scale (CRS), the BCC model does not. The BCC model is therefore used for analyzing variable returns to scale (VRS) situations. We use both the BCC and CCR models to calculate relative efficiency scores and scale efficiencies.

The “best performance” or “efficient” frontier is the boundary of the convex hull of the set of efficient companies in the input/output space (Charnes et al., 1978; Deprins et al., 1984; Fare et al., 1985; Banker, 1993). Two basic approaches exist in DEA to estimate this frontier. The first in input-oriented, the second output-oriented. In an input orientation, outputs are fixed at their observed levels and companies are expected to proportionally reduce their input levels in the direction of their efficient peers. In this case, an RTC is not efficient if it is possible to increase any output without increasing any input and without decreasing any other output. If, on the other hand, an output orientation is chosen, the input levels are fixed and the possibility of a proportional increase of the created outputs is explored. In this input-oriented model, an RTC is not efficient if it is possible to decrease any input without increasing any other input and without decreasing any output. The latter orientation is considered the most appropriate in the context of

this paper, because the assets and workforce[3] of the RTCs are usually rather fixed. The challenge for these companies lies in generating more profit and/or added value with these given inputs. Measures that can be taken to attain this goal are e.g. increasing marketing activities or engaging in projects such as horizontal cooperation.

Because of its ability to model relationships with multiple inputs and multiple outputs without *a priori* assumptions on the underlying functional form, DEA has been applied in numerous areas (Seiford (1997) provides a DEA bibliography until 1996). One of the main areas of DEA application has been transportation and logistics. However, most emphasis in the literature on this domain is on airliners' efficiency (e.g. Adler and Golany, 2001; Chiou and Chen, 2006), seaports (e.g. Pestana Barros and Athanassiou, 2004; Turner et al., 2004), urban transport systems (e.g. Boame, 2004; Karlaftis, 2004), and traffic safety (e.g. Mejza and Corsi, 1999; Odeck, 2006). As far as logistics is concerned, DEA applications mainly focus on customer-supplier relations (e.g. Kleinsorge et al., 1991; Narasimhan et al., 2001), and in-company logistics processes of production companies (e.g. Clarke and Gourdin, 1991; Ross and Droge, 2004). However, until now little attention has been paid to the efficiency of third parties that perform logistics services for shippers. Taking into account the economic importance of these LSPs, we consider this to be an important gap in the literature, and the current study is aimed at filling this gap.

The general output-oriented DEA model is formulated below. This model has to be solved for every RTC in our data set. In the formulation below there are *J* inputs, *I* outputs, and *K* RTCs. x_{kj} represents the amount of input *j* that RTC *k* uses and y_{ki} is the amount of output *i* that RTC *k* produces. λ_k is the multiplier with respect to the k^{th} RTC for the RTC under consideration (*k'*). Companies with $\theta = 1$ are considered efficient relative to the other companies. Constraint set (2) ensures that the used amount of each input *j* by *k'* is a linear combination of the used amounts of inputs by relatively efficient RTCs plus the possible excess input of RTC *k'*. Constraint set (3) states that the output levels of *k'* should be a linear combination of the output levels of relative efficient RTCs. In the output-orientation of DEA, the outputs $y_{k'i}$ should grow to $\theta y_{k'i}$ to achieve relative efficiency taking into account the fixed current input levels of RTC *k'*. The model generates an efficient piece-wise linear frontier of relative efficient RTCs. In the case that *k'* has a $\theta > 1$, a composite RTC could be configured from the RTCs along the efficient frontier that uses the same inputs levels, but produces more outputs than *k'* currently does. Therefore, the larger θ, the more inefficient RTC *k'* is. Constraint set (4) is only relevant for VRS case (i.e. the BCC model), and can be ignored in the BCC model with CRS.

[3] In total 96.5% of the hours worked in the Flemish road transportation sector is made by employees on a fixed contract.

$$\text{Max}\ \theta \tag{1}$$

$s.t.$

$$x_{k'j} \geq \sum_{k=1}^{K} \lambda_k x_{kj}, \qquad j = 1, 2, ..., J \tag{2}$$

$$\theta y_{k'i} \leq \sum_{k=1}^{K} \lambda_k y_{ki}, \qquad i = 1, 2, ..., I \tag{3}$$

$$VRS : \sum_{k=1}^{K} \lambda_k = 1 \tag{4}$$

$$\lambda_k \geq 0 \tag{5}$$

$$k = 1, 2, ..., K$$

3.1 Inputs and outputs

The production process of RTCs is represented by the use of multiple inputs to produce several outputs. In general, their total inputs are a combination of

- labour (e.g. total wages, (drivers') experience, total hours worked, number of employees, etc.),
- equipment (e.g. number of trucks, number of trailers, total loading capacity etc.), and
- intangible assets (market information, customer contacts, goodwill etc).

Unfortunately, information on most of these inputs is not available in the heavily fragmented and under-digitalized Flemish road transportation industry. The inputs that are available for each company in this study are the total assets and the number of hours worked. Given the fact that in the road transportation sector there are very few unique or scarce technologies that greatly enhance performance and as a result a large share of total assets is represented by basic equipment such as trucks and trailers, these two inputs provide a good approximation of the underlying measures. Outputs can also be subdivided into several categories, such as turnover, added value, profit, vehicle utilization, kilometres driven, customer satisfaction, average payload, average price paid per loadmeter, number of deliveries on time, etc. Moreover on the output side, obviously not all information is available for these output categories. Although there are disadvantages of working with monetary figures under DEA, in this specific case it would be incorrect to focus on only a limited number of (physical) outputs, because excluding the remaining ones would not render the company's delivered quality of service and would therefore certainly bias the DEA results. For example, it might be possible to retrieve the kilometres driven by a company, but this would give no information about efficiency without knowledge of e.g. vehicle utilization or the price paid per loadmeter by the customers. Therefore, the decision was to work with two compound monetary outputs that provide a good summary of the separate output components mentioned above. These are added value and profit.

We found significantly positive correlation coefficients among inputs and outputs as shown in Table 6, confirming that the input/output data of the 82 respondents satisfy the hypothesis of isotonicity underlying DEA. During the whole process of analysis we use the assumption that all defined inputs affect production levels.

Table 6
Correlation coefficients between variables (significance levels between brackets)

		TA	HOUR	AV	PR
Inputs					
Total assets, 2003, kEURO	TA	-			
Hours worked, 2003	HOUR	0.922 (0.000)	-		
Outputs					
Added value, 2003, kEURO	AV	0.953 (0.000)	0.979 (0.000)	-	
Profit/loss for the year before taxes, 2003, kEURO	PR	0.599 (0.000)	0.669 (0.000)	0.693 (0.000)	-

Table 7 shows the average input and output levels of the different categories of responding RTCs. In addition, the Flemish road transportation market averages are reported in the far right column. It is clear from the table that the larger companies cooperate horizontally or are interested in doing so more often than SMEs.

Table 7
Average inputs and outputs

	Cooperator	**non-cooperator**	**Interested**	**Not interested**	**Contracted Annual account**	**Complete annual account**	**Overall**	***Flanders***
n	33	49	34	48	61	21	82	2784
Inputs								
-HOUR	84270	28512	91435	22275	17593	147849	50951	28047
-TA	2895	1305	3282	998	750	5414	1945	1823
Outputs								
-AV	2701	875	2829	746	568	4637	1610	929
-PR	172	33	158	40	24	276	89	51

4. Performance evaluation and horizontal cooperation

The AIMSS modelling system is used to calculate CRS and VRS efficiency levels and scale efficiencies for

1. the entire Flemish road transportation sector (resulting in 2 DEAs),
2. the complete set of 82 usable respondents (resulting 2 DEAs), and
3. subgroups of these respondents based on the categorizations in Table 4 (resulting 12 DEAs).

The results can be found in Table 8 and the corresponding explanation is organized as follows. Section 4.1 discusses CRS and VRS efficiency scores, Section 4.2 focuses on the scale efficiencies, and finally in Section 4.3 the conjectures are tested based on the DEA results.

4.1 CRS and VRS Efficiency levels

For both the VRS and CRS models, frequencies and cumulative percentage frequencies are tabulated in Table 8 for eight groups of RTCs. Six of these groups are subgroups of the set of respondents, being the cooperators, non-cooperators, interested respondents, non-interested respondents, respondents with a complete annual account, and respondents with a contracted annual account. Finally, DEA results are

displayed for the complete set of respondents and for the entire population of Flemish RTCs, of which the respondents of course form a subset. To calculate the efficiency levels for responding RTCs, we perform the DEA on the entire Flemish road transportation sector and use the thus calculated efficiency levels. This renders the analysis more robust since the sample was constructed randomly from all Flemish RTCs and obviously there is no reason why the efficient frontier would consist of companies which are respondents to the questionnaire.

The most prominent conclusion to be drawn from the results in Table 8 is that there is ample room for improvement amongst the Flemish RTCs. The far right column of Table 8 indicates that only 1% in the CRS case and 5% in the VRS case (1.2% and 4.6% to be more exact) comes within reasonable distance (i.e. efficiency scores <1.5)[4] of the frontier formed by the efficient RTCs. Median efficiency scores for (subgroups of) respondents vary from 2.70 to even 2.91 in the CRS case and from 1.73 to 2.74 in the VRS case. Although at this point no final conclusions can be drawn, it would appear that the cooperating respondents are more efficient than their non-cooperating colleague RTCs (median scores of 2.70 vs. 2.91 and 2.30 vs. 2.74). Similarly, for the time being we might infer that in the road transportation sector, it is "good to be big". This is supported by the better efficiency levels of companies with a complete annual account, compared to those respondents with a contracted annual account.

To better observe structural differences within the three categorizations of the respondents set, e.g. structural differences in efficiency scores between cooperators and non-cooperators, it is appropriate to apply DEA to each subgroup separately in order to construct efficient frontiers formed by RTCs from the same subgroup. To this end, we calculated two separate DEA models (cf. Ross and Droge, 2004; Johnes, In press). These models, called "Before Frontier Projection" and "After Frontier Projection" consequently have different dimensions and reference sets. For the "Before" model the subgroups of respondents were analyzed both individually and independently. The efficiency scores that result from these DEAs can be found in Table 9 under "Before". To arrive at the results for the "After" model, we projected the separate subgroups on their respective efficient frontiers[5]. Then the total group of respondents is joined again and an aggregate DEA is conducted to arrive at the "After" efficiency scores in Table 9. This procedure is performed three times: for cooperators/non-cooperators, for interested/non-interested respondents and for respondents with a contracted/complete annual account. This frontier projection approach removes the managerial component of inefficiencies, leaving the 'structural' inefficiencies of the subgroups unaltered. Charnes et al. (1981) refer to this as *programmatic (in)efficiency*. Non-parametric tests can then be employed to find possible significant differences in programmatic efficiency.

[4] Note that an efficiency score of 1.5 means that an RTC could have produced 50% more with its current inputs, were it efficient.

Table 8
Efficiency scores with respect to complete population of road transportation companies

	Cooperators		**Non-coop.**		**Interested**		**Non-Interest.**		**Complete**		**Contracted**		**Respondents**		**Flanders**	
CRS Eff.	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
1 – 1.5	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	33	1%
1.5 - 2.5	8	24%	13	27%	9	26%	12	25%	5	24%	16	26%	21	26%	547	21%
2.5 - 3	18	79%	17	61%	16	74%	19	65%	11	76%	24	66%	35	68%	737	47%
3 – 5	7	100%	18	98%	8	97%	17	100%	5	100%	20	98%	25	99%	1264	93%
> 5	0	100%	1	100%	1	100%	0	100%	0	100%	1	100%	1	100%	196	100%
Average	2.83		2.93		2.95		2.85		2.85		2.90		2.89		3.43	
St. dev	0.49		0.69		0.70		0.56		0.55		0.64		0.62		3.20	
Median	2.70		2.91		2.80		2.81		2.76		2.83		2.80		3.06	

	Cooperators		**Non-coop.**		**Interested**		**Non-Interest.**		**Complete**		**Contracted**		**Respondents**		**Flanders**	
VRS Eff.	n	%	n	%	n	%	n	%	N	%	n	%	n	%	n	%
1 - 1.5	9	27%	2	4%	9	26%	2	4%	9	43%	2	3%	11	13%	127	5%
1.5 - 2.5	11	61%	16	37%	10	56%	17	40%	7	76%	20	36%	27	46%	801	33%
2.5 - 3	7	82%	19	76%	10	85%	16	73%	4	95%	22	72%	26	78%	697	59%
3 - 5	6	100%	11	98%	4	97%	13	100%	1	100%	16	98%	17	99%	1007	95%
> 5	0	100%	1	100%	1	100%	0	100%	0	100%	1	100%	1	100%	140	100%
Average	2.27		2.68		2.29		2.67		1.87		2.74		2.52		3.10	
St. dev	0.85		0.71		0.93		0.63		0.65		0.71		0.79		2.54	
Median	2.30		2.74		2.19		2.71		1.73		2.72		2.57		2.82	

	Cooperators		**Non-coop.**		**Interested**		**Non-Interest.**		**Complete**		**Contracted**		**Respondents**		**Flanders**	
Scale Index	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
0 - 0.25	3	10%	9	18%	9	26%	8	17%	1	5%	13	21%	14	17%	501	18%
0.25 - 0.5	3	19%	10	39%	10	56%	11	40%	1	10%	12	41%	13	33%	541	37%
0.5 - 0.75	2	26%	8	55%	10	85%	7	54%	1	14%	9	56%	10	45%	379	51%
0.75 – 1	2	32%	5	65%	4	97%	4	63%	0	14%	7	67%	7	54%	272	61%
1 - 2.5	10	65%	12	90%	1	100%	14	92%	4	33%	18	97%	22	80%	602	82%
> 2.5	11	100%	5	100%	0	100%	4	100%	14	100%	2	100%	16	100%	488	100%
Average	3.69		1.46		4.03		1.16		6.39		0.97		2.35		1.85	
St. dev	5.71		2.46		6.00		1.32		6.72		1.08		4.20		4.26	
Median	1.49		0.70		1.41		0.73		4.61		0.67		0.89		0.73	

Table 9
The "Before" and "After" DEA models

	Cooperator			**Non-Cooperator**			**Interested**		
CRS	Before	After	%	Before	After	%	Before	After	%
Average	1.218	1.084	11.0%	1.383	1.005	27.4%	1.307	1.064	18.6%
Stand. Dev.	0.214	0.084	60.6%	0.306	0.017	94.3%	0.305	0.100	67.2%
Median	1.177	1.059	10.0%	1.350	1.000	25.9%	1.214	1.016	16.3%
VRS	Before	After	%	Before	After	%	Before	After	%
Average	1.115	1.063	4.6%	1.202	1.050	12.6%	1.165	1.055	9.5%
Stand. Dev.	0.170	0.155	8.9%	0.242	0.095	60.6%	0.240	0.156	35.0%
Median	1.056	1.008	4.6%	1.137	1.007	11.5%	1.099	1.001	8.9%
	Non-Interested						Complete annual account		
CRS	Before	After	%	Before	After	%	Before	After	%
Average	1.300	1.034	20.5%	1.154	1.164	-0.8%	1.365	1.000	26.7%
Stand. Dev.	0.238	0.036	85.0%	0.197	0.061	69.1%	0.285	0.000	100.0%
Median	1.263	1.029	18.6%	1.089	1.141	-4.8%	1.324	1.000	24.5%
VRS	Before	After	%	Before	After	%	Before	After	%
Average	1.156	1.065	7.9%	1.086	1.039	4.3%	1.233	1.026	16.8%
Standard deviation	0.180	0.085	52.8%	0.162	0.088	45.9%	0.255	0.046	81.8%
Median	1.072	1.052	1.9%	1.003	1.000	0.3%	1.175	1.005	14.5%

4.2 Scale efficiencies

Following Banker (1984) we know that the economic scale of each RTC can be measured by its scale index (i.e. $\sum \lambda_j$ in the CRS model). A company with a scale index of 1 operates at its most efficient scale. When $\sum \lambda_j < 1$, this company experiences increasing returns to scale (IRS) and should expand. When on the other hand $\sum \lambda_j > 1$ there are decreasing returns to scale (DRS), meaning that the company would benefit from downsizing it operations. In line with our procedure for generating VRS and CRS efficiency levels in the previous section, we use the DEA of the total Flemish sector and then use the scale indices of the RTCs in the respondents set (see Table 8).

4.3 Testing of the conjectures

In this section we describe the DEA results step by step by discussing and testing the seven conjectures formulated in Section 1.

C1: Larger companies are more efficient

The first conjecture states that larger RTCs are more efficient than smaller ones. In order to test this conjecture, we need a measure of the size of an RTC. Since the total hours worked and the total assets together resemble the reasonably fixed working capital of an RTC, we chose to use the following construct $S(k)$ as our indicator of the size of RTC k:

$S(k) = HOUR(k)/\overline{HOUR} + TA(k)/\overline{TA}$, where $\overline{X}$ is the sector average value of input X.

Consequently, we correlate S(k) with the vector of VRS efficiency scores of the respondents as calculated when taking the entire population of Flemish RTCs into account.

Figure 2 shows the corresponding scatter plot. It resembles a statistically significant correlation coefficient of –0.532 (Asymp. Sig. = 0.000). This negative relation means that larger companies are likely to have a smaller θ value, and are therefore more efficient than smaller RTCs. This is in line with our expectations, which were based on the fact that being small (e.g. having only a limited numbers of vehicles) strongly limits a company's ability to fulfil today's strict customer requirements in terms of costs, flexibility and speed. Conjecture 1 is therefore supported.

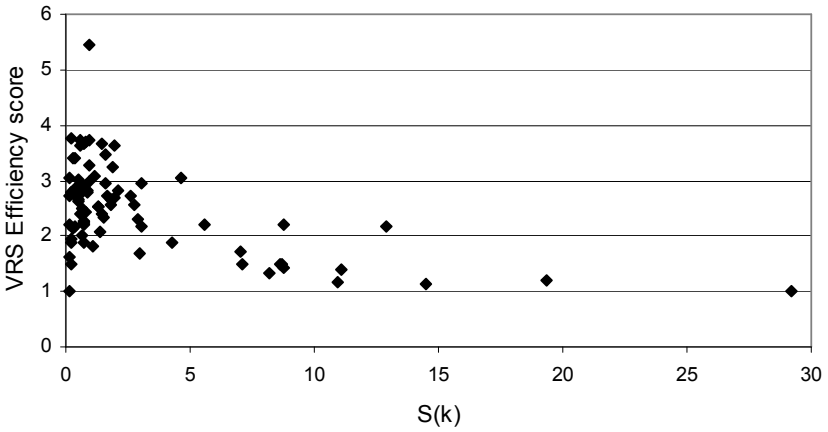

Figure 2. Conjecture 1

C2: The Flemish transportation market is too fragmented.
We state that the Flemish road transportation market is too fragmented if a disproportionate share of RTCs are operating below their most productive scale size (mpss). Results by Banker (1984) tell us that the scale index determines whether a company is operating below, at, or above its mpss. We therefore focus our discussion of the present conjecture on the scale indices at the bottom of Table 8. It turns out that in Flanders as a whole, 61% of RTCs are operating below their mpss and the median scale index is 0.73. This suggests that the Flemish road transportation sector would benefit from scale expansion of presently active RTCs and as a result conjecture 2, stating that the Flemish road transportation market is too fragmented, is supported. Taking into account the relatively stable market size, the most obvious scenarios for this expansion would be mergers, takeovers or horizontal cooperation between existing RTCs.

When we take a further look at the scale indices in Table 8, we see that there exist some interesting differences between the various categorizations. It is no surprise that the RTCs with a complete annual account show greater scale indices than the RTCs with a contracted account. As indicated in Section 2.1, the latter can be considered 'small' companies while the former fall into the category of 'large'. However, the median scale index of the responding RTCs with a complete annual account is strikingly large (4.61), meaning that these companies operate far above their mpss. This, together with the fact that the respondents with a contracted annual account have a median scale index below 1 (0.67) once again suggests the existence of an ideal firm size somewhere in between the complete and contracted annual account firm sizes. A second observation is that cooperating RTCs and RTCs that are interested in setting up or intensifying horizontal cooperation tend to operate above their mpss (scale indices of 1.49 and 1.41, respectively). From this we may conclude that in the terms of Verstrepen et al. (2006), horizontal cooperation is more frequently considered a 'defensive' strategy aimed at rationalizing inputs and

defending turnover or market share, rather than an 'offensive' strategy to enter new markets or actively attract additional clients in present markets.

C3: Cooperating companies show greater efficiency levels than non-cooperating companies

The third conjecture states that cooperating RTCs are more efficient than non-cooperating RTCs. To test this, we use the efficiency scores of the (non-)cooperating respondents as they are displayed in Table 9. Charnes et al. (1981) refer to the separate sets of companies that make up the efficient boundaries for (in this case) cooperating and non-cooperating RTCs as the α-envelopes. Table 9 outlines the adjustment of the outputs of both sets of RTCs onto their corresponding α-envelope. In this way, each RTC is forced to become as efficient as its most efficient peer in the same subgroup of respondents. This frontier projection removes managerial efficiency (e.g. in the CRS case, leaving out the managerial efficiency improves the average efficiency scores of companies with a contracted annual account from 1.37 to 1.11), and tests for significance of programmatic efficiency differences can be conducted. In the case of conjecture 3, the two 'programs' are 1) Cooperating RTCs, and 2) Non-cooperating RTCs. We used the non-parametric Mann-Whitney test to compare the "After" efficiency scores of cooperators vs. non-cooperators. If present, this test procedure will find significant differences in the rank distributions of efficiency scores for the (non)cooperating RTCs. The results are at the top of Table 10. As it turns out, there is no significant difference between the efficiency levels of cooperating and non-cooperating RTCs, and conjecture 3 is rejected.

Table 10
Conjectures 3 and 4

	Number of RTCs	Average rank of VRS Efficiency level	Mann-Whitney U	Asymp. Sig.
Cooperators	33	41.24	800	0.935
Non-cooperators	49	41.67		
Interested	34	33.15	532	*0.007*
Not interested	48	47.42		

C4: Companies interested in (intensified) cooperation are more efficient than companies that are not interested.

Table 8 already suggests that in the VRS case efficient firms are more interested in initiating or increasing the intensity of horizontal cooperation: the median efficiency scores for interested RTCs is 2.19, whereas for non-interested RTCs it is 2.71. In order to get a more reliable comparison between the two subgroups however, we once again employ the frontier projection procedure outlined under C3 to arrive at the results at the bottom of Table 10. Indeed, the expected difference between efficiency levels of interested and not interested RTCs is statistically significant at the 0.01 level, and the conjecture is supported. Horizontal cooperation is thus unlikely to find solid ground at companies that are operating very inefficiently. On the other hand, a more sound business might be in the position where internal processes are more or less optimized and cooperation with sister companies offers an interesting opportunity to improve the company's achievements.

C5: Larger companies cooperate more often than smaller ones.

To evaluate this conjecture, we use the Mann-Whitney test and compare the S(k) construct of cooperators vs. non-cooperators. Table 11 shows that conjecture 5 is supported at the 0.01 level: larger companies cooperate horizontally more often than their smaller counterparts. In response to open questions in the questionnaire (see Cruijssen et al., in press), many respondents indicated that they considered themselves

too small to engage in a horizontal cooperation. The rationale behind this is that many RTCs in the smallest category have 5 trucks or less. This means that often the director/owner also drives a truck, which limits his time for managerial tasks, including research into novel business opportunities such as horizontal cooperation.

Table 11
Conjecture 5

	Number of RTCs	Average rank of S(k)
Cooperator	33	49.85
Non-cooperator	49	35.88
Mann-Whitney U	533	
Asymp. Sig.	0.009	

C6: Less efficient companies value the opportunities of cooperation higher than more efficient companies do.

For the assessment of this conjecture we correlated the VRS efficiency scores of the respondents with their evaluations of the propositions about opportunities of horizontal cooperation, which are listed in Table 2. The results in Table 12 indicate that this conjecture must be rejected: none of the advantages shows a significant correlation with efficiency. It can be concluded that respondents subscribe to the advantages, irrespective of their efficiency level. This puts our discussion under conjecture 4 into a broader perspective: (heavily) inefficient RTCs admit that horizontal cooperation can bring value to their business, but they are simply not ready for it yet.

Table 12
Conjectures 6 and 7

Proposition	Correlation Coef.	Sig. (1-tailed)
O1	-0.002	0.494
O2	0.045	0.348
O3	0.098	0.199
O4	0.138	0.116
O5	-0.004	0.487
O6	-0.027	0.408
O7	0.050	0.334
I1	0.123	0.140
I2	0.025	0.412
I3	0.223	0.025
I4	0.038	0.371
I5	0.137	0.116
I6	0.151	0.095
I7	-0.010	0.466
I8	0.339	0.001
I9	-0.042	0.359

C7: Inefficient companies consider the impediments for horizontal cooperation to be more severe than less efficient firms do.

Table 12 shows that this conjecture is not supported in general. The evaluations of two disadvantages however, show a significant positive correlation with the VRS efficiency of RTCs, meaning that inefficient RTCs consider these disadvantages to be more severe. They are I3 ("It is hard to determine the benefits or operational savings due to horizontal cooperation beforehand.") and I8 ("Benefits cannot be

shared in a fair way; the larger players will always benefit most."). A factor common to these two impediments is that they are the ones that might occur first to those RTCs who have no experience to date with horizontal cooperation. Inefficient RTCs are appropriately very cautious about unfair gain sharing and about the expected payoff of such a project, since some of them will not have the financial buffer required to survive a failed project.

5. Concluding remarks

The goal of this paper was to employ DEA on empirical data and to draw conclusions regarding 1) the efficiency of the Flemish road transportation sector and 2) the potential of horizontal cooperation to improve its competitiveness. DEA proved to be a useful tool in empirically identifying frontiers of efficient companies and measuring the relative efficiency levels of the remaining companies.

The data used in this study came from the respondents to a large-scale survey among Flemish Logistics Service Providers conducted in 2003. This survey focused on horizontal cooperation, and this concept was explicitly incorporated in our DEA approach. Based on their answers to survey questions, respondents were categorized three times, depending on 1) whether or not they were currently cooperating horizontally, 2) whether or not they were interested in (intensifying) horizontal cooperation, and 3) the respondent's type of annual account, the latter being an indicator of firm size. Following Ross and Droge (2002), in order to make reliable statements about efficiency differences between such groups, we used ordinal ranks and the Mann-Whitney procedure. Our analysis set contained 82 road transportation companies, which accounts for 2.9% of the total Flemish road transportation sector[6]. Although this percentage is relatively low, the random manner is which the surveyed sample was constructed, strengthens our belief that the results presented provide a good indication of the situation across the entire Flemish road transportation sector.

The main contributions of this paper come from the results of the conjectures formulated in Section 1. Most importantly, the Flemish road transportation sector turns out to be highly inefficient: less than 5% of the responding companies come even within reasonable distance of the efficient frontier. Nevertheless, this does not devalue the sector's importance in the success of Flanders as a preferred location for European Distribution Centres (Sleuwaegen et al., 2002). Conjectures 1 and 2 revealed that an important reason for this inefficiency lies in the strong fragmentation of the sector. This is illustrated by the fact that Flanders houses 4 667 RTCs, or one RTC per 1 285 inhabitants. Horizontal cooperation is put forward as a possible resolution, by rationalizing on inputs and boosting a company's efficiency. We consider the scale inefficiency found in the research strong enough to expect that severe future market consolidation will be needed in order for the sector the remain competitive with foreign (Eastern-European) RTCs. The main lesson learned from conjectures 3 to 5 is that horizontal cooperation is not easy. A minimum degree of efficiency and scale is needed before the impediments can be overcome and rewards can be reaped. Finally, conjectures 6 and 7 examined the relation of RTCs' efficiency levels with their attitudes towards opportunities of and impediments for horizontal cooperation. No significant difference in the evaluations of the opportunities between efficient and less efficient RTCs could be found. This means that even the inefficient RTCs think that horizontal cooperation can improve their business, but their bad (financial) performance makes it problematic. They cannot afford to spend time and money on starting up a horizontal cooperation project and/or run the risk of a failed project. This is also the most likely

[6] We only incorporate companies in which at least 1500 hours were worked in 2003.

explanation for the fact that inefficient companies consider two impediments to be more severe than their more efficient counterparts.

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