Efficiency in transport logistics

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Abstract

Efficiency in transport logistics can be evaluated from several aspects: from the point of view of the service provider, from the perspective of the customer, or that of the government and from the point of view of sustainability. Efficiency will always mean approximately the same thing but emphasis might shift from the strictly financial aspect to the social and environmental side as the perspective is changed.

Based on international research findings and European level projects the first part of the article attempts to clarify the definition of efficiency and highlight the scientific fields, methods and methodologies within the boundaries of transport logistics which contribute to efficiency. As these range from technical, technological and IT solutions through economic measures to organisational and legal instruments the spectrum is very wide indeed.

Thus the second part of the paper narrows down the scope of research to efficiency enhancement methods related to cost and performance management as these offer viable and practical solutions for evaluation and for achieving results in the short term. One such method presented here is the evaluation of technical efficiency e.g. through data envelopment analysis and its variations which dispose of the necessary theoretical background and so can be adapted to the desired transport mode or even intermodal chain.

Another solution is the improvement of cost calculations in transport logistics by combining accounting and technology information. The main idea of such cost management procedures is that indirect costs are allocated to profit objects of logistics chains in a cause-effect based way by using suitable performance indicators. By doing so cost calculations can be made more reliable and prevent distortions caused by simple averaging of aggregated cost data.

Both methodologies are analysed mainly from theoretical point of view with special regard to their practical applicability. Limitations and conditions of the implementation are also considered.

Keywords: transport, logistics, efficiency

INTRODUCTION

Ever since the birth of the first undertaking the aim of managers and executive officers has been to realise the maximum revenues possible, while customers expect quality service for a reasonable price, and governments insists on the adherence to the applicable legal framework. The last decade has brought about a new criterion, that of sustainability which is a novel aspect to be taken into account.

In our research work we examined a number of projects dealing with some aspect of transport logistics, trying to capture the characteristics that could contribute to efficiency (Section 2). Having realized that the range of themes is very wide, we attempted to clarify the definition of transport efficiency (Section 3), and then chose two methods (data envelopment analysis and activity based costing – Section 4 and 5) which can play a major role in reaching efficiency and investigated how they can be implemented.

A REVIEW OF PROJECTS CONTRIBUTING TO EFFICIENCY

The authors of this paper reviewed a number of European level and some national research projects with the sole objective in mind of pinpointing the factors that can or could contribute to efficiency when applying the results of these research works. Being perfectly aware that such a summary could never be complete, nonetheless some themes have emerged as fields which seem to be significant in efficiency enhancement. The application of telematics, dissemination of information and improvement of management, intermodality, invention of new techniques and technologies, the presence of sustainability are the sometimes overlapping fields around which the majority of projects can be clustered. While highlighting the different areas we were intent on giving examples which illustrate best the significance of the given theme, although the same project could be important in a different field as well.

One part of current national and European level projects have the aim of making a greater use of the possibilities lying in modern telematic systems. These contribute to efficiency through better localisation (tracking and tracing) of the vehicles or even the freight being transported. The most significant European research projects relevant to this field have various goals: creating a common and harmonised tracking and tracing in the road and railway sector (CESAR II), tracking and tracing on parcel level in the same transport modes using RFID (ParcelCall), surveillance and protection of the goods in the road sector (ASAP), enabling the transportation of the goods in a transport crate equipped with RFID (iBoS), creation of a virtual fleet for the small haulage companies to make them more competitive (TROP), port organisation, better navigation, sustainability (EFFORTS), the creation of a freight transport monitoring system and a transport chain management system for intermodal chains (D2D), use of freight information in the railway environment (FIRE), monitoring cross border train movement in real time (BRAVO), offering one-stop-shop freight managements for SMEs (GIFTS) and rail car asset management (F-MAN). Thus one element of efficiency could be that of the use of telematic systems which provide the companies with more reliable information on the place (and recently sometimes even the state) of the goods.

Another dimension of efficiency is the availability of information needed for more efficient operations. There are a number of projects which deal with the dissemination of information and with the efficient tools of information. Examples include projects with the aim of creation and dissemination of logistics best practice (BESTLOG), of dissemination of information (CENTRAL LOCO), of making available information and communication tools for secure and efficient information exchange in intermodal chains (SESTANTE), of managing and integrating information on the inland waterways (IP), of creating a global integrated transport logistics data network for intermodal chains (GILDANET). A closely related field is that of the enhancement of management, which is not only achieved by higher quality information but harmonised standards as well. Projects that can be mentioned in this field aim at the creation of an improved management and information exchange (FREIGHTWISE), the harmonisation of standards (D4D) or the invention of a terminal simulation system (TRAPIST) (Site and Salucci, 2009), (Winder, 2009).

Another echelon of improving efficiency is that of intermodality, the enhancement of which has long been a priority of the European Union. In order to achieve intermodality, a number of new systems are being developed. Examples include umbrella projects covering different transport modes on European level, like the Vessel Traffic Management and Information System (VTMIS) integrating several systems, such as the Automatic Identification System (AIS) and the Long Range Identification and Tracking (LRIT systems) in maritime transport, the River Information Services (RIS) for inland waterways, the European Rail Traffic Management System (ERTMS) and the European Air Traffic Management System within SESAR (Single European Sky ATM Research) (European Commission, 2008). Of course, several smaller projects could also be cited as example here, but as they are in the reach of other themes as well, they are not mentioned here, but under the heading of "intermodal chains" within their given topic.

Novel techniques and technologies together with new IT solutions can also provide important steps towards more efficient transport logistics. The following European level projects invent new technical solutions and thus influence the efficiency as well: VRSHIPS-ROPAX, with the goal to examine ship technologies through the creation of a platform; BRAVO, to monitor cross border train movements in real time; FASTRCARGO, to create a new loading system in order to speed up loading/unloading at the railways; CARGOSPEED, to accelerate cargo and rail interchange, INTEGRATION, for integrated and improved ship-shore systems, INTERGAUGE, to create a new freight movement technology for railways and ISTU to invent an integrated standard transport unit for self-guided freight-container transportation systems on rail (Site and Salucci, 2009).

Table 1.

Examples from the different fields

	Road transport	**Rail transport**	**Inland waterways**	**Ports and/ or maritime transport**	**Intermodal chains**
Telematics	CESAR II ParcelCall ASAP iBoS TROP GIFTS	CESAR II ParcelCall FIRE BRAVO F-MAN		EFFORTS	D2D
Information andmanagement	BESTLOG CENTRAL LOCO FREIGHTWISE	BESTLOG CENTRAL LOCO FREIGHTWISE	BESTLOG CENTRAL LOCO IP FREIGHTWISE D4D	BESTLOG CENTRAL LOCO TRAPIST FREIGHTWISE	BESTLOG CENTRAL LOCO SESTANTE FREIGHTWISE GILDANET
Inter-modality		ERTMS	RIS	VTMIS (AIS, LRIT, etc.)	not applicable
tech nolo gy		BRAVO FASTRCARGO CARGOSPEED		VRSHIPS-ROPAX	

	INTEGRATION	INTERGAUGE ISTU		INTEGRATION	INTEGRATION
Sustainability (external costs)	SPI	SPI	SPI RECORDIT		SPI RECORDIT

[*source: own compilation*]

Finally, paying attention to sustainability and external costs can also pave the way for more efficient operations especially now that the pressure is getting bigger on companies to incorporate these aspects into their management. Operating in a sustainable way can also amount to comparative benefit. Environmental awareness is in the focal point of more and more research studies (see e.g. (Nagy et al., 2009), (Markovits-Somogyi et al., 2009)). Two, separate projects have dealt with this aspect of transport logistics as well. A Hungarian research project looked into the evaluation of transport alternatives from the point of view of sustainability, meaning that economic, environmental and social factors were taken into account with the same weights. Using a multitude of indexes the Simongáti introduced a model covering all these three features, calculated the SPI (Sustainable Performance Index), and showed how sustainability can easily be included into the managerial decisions (Simongáti, 2009). A European level research project, RECORDIT aimed to help in the calculation of internal and external costs of intermodal transport thus propagating the choice of this transport mode (Site and Salucci, 2009).

DEFINITION

Having compared several research projects we can see that efficiency is present in very different sectors of innovation and management, but defining it might prove more difficult than expected. "The right thing, at the right price, in the right place, at the right time" as cited by (Goodman and Moss, 1990, pp. 151) is the broadest approach possible, but it summarizes well what is meant by efficiency using common sense. A little bit narrower approach, focusing on transport is taken by O'Sullivan (O'Sullivan, 1980, pp. 82), who defines efficiency as a matter of meeting the needs for movement at the least social cots (*Definition 1.*) Koopmans based his definition on the Pareto criterion. This latter states, that justified social policy is that which makes some persons better off without making others worse off (*Definition 2.*). Koopmans adopted this approach by applying this property to "final goods" (outputs), stating that no final good should be improved if this improvement results in worsening one or more other final goods (*Definition 3.*). This is a very promising definition, as this leads us to the Extended Pareto-Koopmans Definition (*Definition 4.*): which says that full efficiency is achieved by a decision making unit if and only if none of its inputs or outputs can be improved without worsening some of its other inputs or outputs. (Cooper et al., 2004).

However distant and technical this might seem, this is the most promising definition from the point of view of logistics applications. In an output oriented form it can be interpreted in the following way (*Definition 5*): *a transport logistics firm is efficient if and only if none of its outputs can be increased without altering (increasing) one or more of its inputs.* It is reasonable to choose an output oriented approach, as transport logistics companies are predominantly private firms without restrictions on their outputs and intent on generating the largest revenues (highest outputs) possible. We are going to proceed on the basis of this definition, and show how data envelopment analysis is suitable for the evaluation of efficiency in transport logistics. It is obvious that efficiency analyses need detailed cost data too. That is why the second methodology focuses on how costing procedures in transport logistics can be improved.

THE INTRODUCTION OF DEA

METHODOLOGY

Data envelopment analysis (DEA) is a non-parametric linear programming approach capable of comparing the efficiency of companies (decision making units, DMUs) to the efficiency of a virtual company (best practice frontier) created from the data of the best performing firms. (Yu et al., 2008), (Coelli et al., 1999). Its strength lies in its ability to compare DMUs of multiple inputs and multiple outputs, without the need of even using the same dimension for these inputs and/or outputs.

The mathematical background of DEA can be summarized in the following (Cooper et al., 2004): the basis is the solution of the next LP (liner programming) model, where we assume each DMU consumes *m* different inputs, and produces *s* different outputs, so for example DMU_j consumes x_{ij} of input *i*, and produces y_{rj} of output *r*. ε is a non-Archimedean element, defined to be smaller than any positive real number, ϕ is the index of efficiency to be maximised, *s* are the slacks (related to the inputs and outputs), and λ are weights. We also suppose that $x_{ij} \geq 0$, $y_{rj} \geq 0$, and for each DMU there is at least one positive input and one positive output.

(1) $\max \phi + \varepsilon(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+)$ subject to

$$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = x_{i0} \qquad i=1,2,...,m$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = \phi y_{r0} \qquad r=1,2,...,s$$

$$\lambda_j, s_i^-, s_r^+ \geq 0 \qquad \forall i, j, r$$

(1) presents the output oriented CCR (named after the researchers, Charnes, Cooper and Rhodes having introduced it) model, the solution of which yields the results in constant returns to scale. With the addition of a further constraint:

$$\sum_{j=1}^{n} \lambda_j = 1$$

converting the CCR model into the BCC (Banker, Charnes and Cooper) model, a VRS (variable returns to scale) approach is also possible.

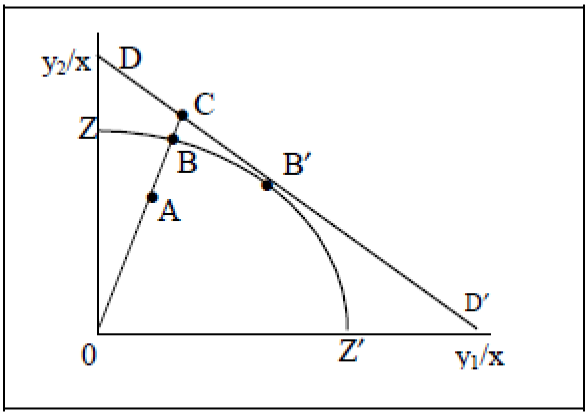

Figure 1. Illustration of the output oriented approach [*source: Coelli, 1996.*]

The output oriented approach can also be illustrated graphically (see Figure 1.) and it enables the definition of technical, allocative and overall efficiency as well (Coelli, 1996): Let us consider a constant returns to scale production process (or a service) where two outputs (y_1, y_2) are created from one input (x). *ZZ'* is the unit production possibility curve, and point *A* depicts an inefficient firm (due to output orientation, below the unit production curve). With *Definition 5.* in mind technical efficiency can be defined as the extent to which the output or outputs can be augmented without having to increase the input. Thus technical efficiency is:

(2) $$TE_O = \frac{0A}{0B}$$

If price information is available, it is possible to draw the isorevenue line, *DD'*, and allocative efficiency can also be defined:

(3) $$AE_O = \frac{0B}{0C}$$

Whereas overall efficiency can be defined as:

(4) $$EE_O = \frac{0A}{0C}.$$

It is worth noting that overall efficiency can be viewed as the product of technical and allocative efficiency, since:

(5) $$EE_O = \frac{0A}{0C} = \frac{0A}{0B} \cdot \frac{0B}{0C} = TE_O \cdot AE_O$$

Finally, it is to be noted that the measures are always limited by the following constraints:

(6) $0 \le TE_0 \le 1$
(7) $0 \le AE_0 \le 1$
(8) $0 \le EE_0 \le 1$.

APPLICATION TO TRANSPORT LOGISTICS

Having understood the theoretical background of data envelopment analysis, it is clear that DEA is suitable for the efficiency evaluation of companies involved in transport logistics. As transport logistics embraces a multitude of transport modes and solutions, in the present article we only focus on how DEA can be applied to non-asset based logistics providers. These 4PL providers do not possess own means of freight forwarding, but have the expertise and the negotiation skills to organise the freight forwarding for their customers. In this way they do business with several freight forwarders and are required to manage whole chains of transport.

The successful application of DEA lies in the right choice of inputs and outputs. As the first step, we have identified the inputs and outputs that could theoretically be used for the evaluation of 4PL logistics providers (see Table 2.). The inputs have been grouped around labour, expertise and capital, while the outputs have been categorized as operational and fiscal factors along with features referring to quality and sustainability.

Table 2.

Possible inputs and outputs for the DEA of companies involved in transport logistics

Inputs		**Outputs**	
Labour	Number of employees	Operational	Number of consignments
	Cost of labour		Amount of freight forwarded (tons and/or TEU)
Expertise	Rate of number of employees with experience and/or studies in the logistics field	Fiscal	Earnings before interest and taxes
	Total number of years spent by the employees in the logistics field		Operational revenue by ton and/or TEU forwarded
	1 – rate of administrative personnel	Quality and sustainability	Rate of on time shipments (%)
Capital	Capital invested		Share of intermodal transport (%)
	Fix assets /Available IT solutions		Amount of CO_2 emission
	Operating expenditure		

[source: own research]

IMPLEMENTATION ISSUES

When planning the implementation of data envelopment analysis, we have to consider the limitations of its usage and the conditions under which the method can be applied. A limitation of application is the number of inputs and outputs, as these are constrained by the data available. As a thumb rule the number of observations should be three times greater than the number of the inputs plus outputs. Another condition is that the number of DMUs, that is the number of non-asset based logistics providers should be equal or larger than the product of the number of inputs and outputs.

With all that in mind, in a concrete application – being the next step of our research work – we will select two to four input factors and one to two output factors, depending on the size of the available dataset. Table 2. has been created with the aim of showing the variety of features that could possibly be included in a data envelopment analysis and therefore there are interchangeable factors among the inputs and outputs. A reasonable choice would take into account their relative importance.

When choosing from the inputs and outputs offered, the weights of different aspects have also to be decided on. E.g. if we want to focus mainly on the fiscal position of the 4PL companies we can select outputs from that category, while if sustainability is also to be considered then factors reflecting it cannot be omitted.

Finally, the 4PL providers themselves have also to be selected. Here, the key restriction is the availability of data. Hence only firms with accessible data regarding the chosen inputs and outputs can be incorporated into the study.

IMPROVING COST CALCULATIONS IN TRANSPORT LOGISTICS

PROBLEM IDENTIFICATION

Evaluation of efficiency needs sound data on operational costs. Logistics cost calculation practices are often based exclusively on accounting approaches. Accounting oriented cost calculation methods, however, may deliver distorted information on the cost effectiveness of logistics operations as they use mainly arbitrary cost allocation procedures when distributing indirect costs. The simplified indirect cost allocation is not reliable enough to evaluate costs and profits of elementary logistics processes or services.

Using simplified average cost values may prevent the differentiation between product or service types having various cost structures. This can lead to the unification of the results in cost efficiency related evaluations, which may cause serious misunderstandings. Doing such efficiency calculations in a rough-and-ready way may result even in wrong capacity allocations in logistics chains.

THEORETICAL BACKGROUND OF THE PROPOSED SOLUTION

A possible solution to make logistics cost calculations more reliable and accurate is to include also technology related information in the costing methodology. It means that operations and performance flows in the logistics service structure shall be modelled and (indirect) cost allocations shall be carried out according to the identified cause-effect relationships. Indirect costs are collected first in so called cost objects (organisational units, pieces of machinery, etc. or activities). Each cost object has its own performance indicator and indirect cost items are distributed to profit objects (products or services) by measuring performance consumptions. Thus performance indicators representing and measuring the cause-effect relationships are the key elements of such costing models (Bokor, 2008b and Bokor, 2009).

Two different ways of logistics cost controlling can be identified depending on the perceived role of logistics:

1. functional approach: when logistics is regarded as a background function (a company-intern service) of production;
2. process oriented approach: when logistics is regarded as a coordination tool integrating material and information flows (within a company and/or between companies).

In the first case the "classical" operative cost controlling tools can be adapted to logistics functions. Here the profit objects are mainly manufactured products. A certain part of production costs is caused by (intern) logistics services. Logistics costs can be mainly regarded as indirect costs as they can not be connected to elementary products directly. So special cost objects (e.g. logistics business units, warehouses, etc.) representing the logistics functions shall be added to the manufacturing-oriented cost calculation scheme.

Logistics costs shall be identified and collected in the logistics cost objects. However, the identification of logistics costs in a manufacturing company is in general not easy: logistics related items can hardly be separated from manufacturing costs. This is also the case when seeking performance indicators for logistics cost objects. In possession of the costs and performances of logistics cost objects the calculation of logistics costs of a certain product can be completed: the cost items are transferred from the logistics cost objects to the relevant profit objects by measuring and evaluating the logistics performance consumption.

The basic idea of the process oriented logistics costing approach is similar to the one of the operative cost controlling model: performance flows are traced in the logistics service system and used for allocating indirect logistics costs. Here, however, cost objects are logistics activities while supply chains (or their certain parts) are selected as profit objects. This approach is more suitable for transport logistics as it concentrates on logistics related costs only and inter-organisational issues can also be taken into account in the model.

Relying on the analysis of the theoretical background the method of activity based costing (ABC) is proposed for improving cost calculations in logistics. Some pilot applications of logistics ABC can already be found in the literature (Baykasoglu, 2008), (Comelli et al., 2008). The basic mathematical model supporting its practical implementation is also available (Bokor, 2008a). The following gives a short summary on how to apply ABC in transport logistics by synthesising the main outcomes of related research results. Figure 2 shows the methodology of logistics ABC.

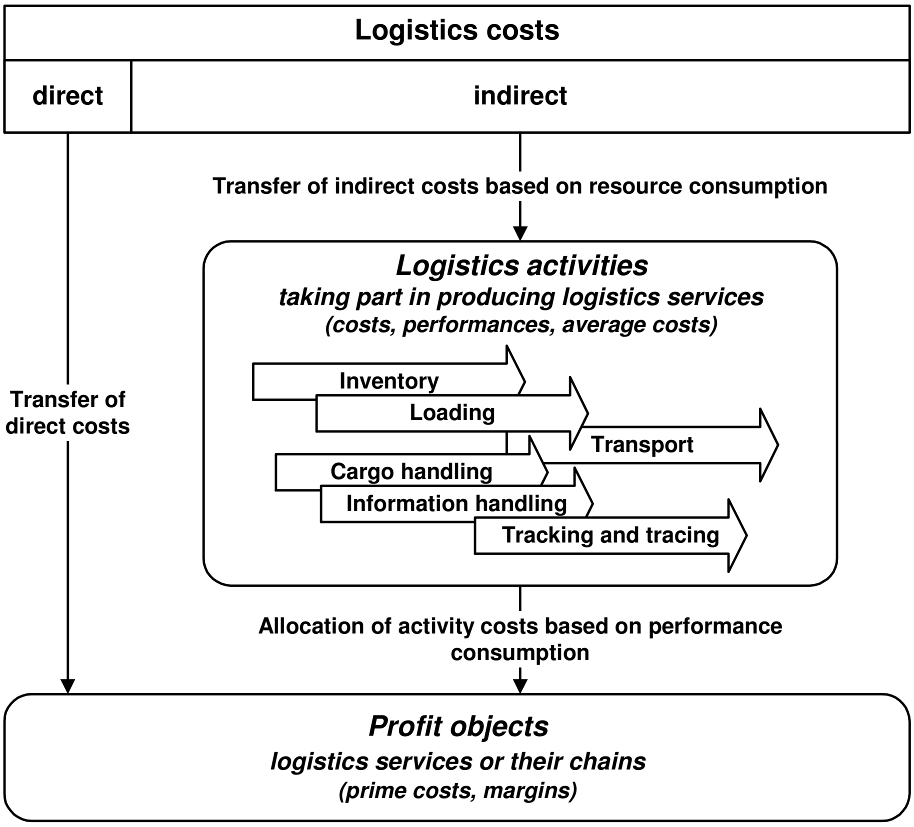

Figure 2. The methodology of logistics ABC
[*source: own edition based on (Bokor, 2008b)*]

Direct logistics costs can be allocated to profit objects (logistics services or their chains) directly. Such cost items could be e.g. the infrastructure user charges. Indirect logistics costs are first assigned to activities as cost objects (like transport, loading, warehousing, providing information, etc.) based on the resource consumption of each activity. This can be carried out mainly by direct cost accounting as the input resources – workforce, machinery, infrastructure elements, etc. – are assigned to activities.

It is essential to find an appropriate performance indicator – e.g. number of handled pieces, operation time, number of orders, vehicle km, etc. – for each activity. Activity costs shall then be differentiated into variable and fix parts according to their relations to performance intensity. A fix cost item can be e.g. the simple time based depreciation while a variable one the piece wage rate.

Each profit object uses various logistics activities and their performances. For example a supply chain of a certain piece of good (as profit object) may make use of activity performances of different disposition as well as physical processes. By measuring the performance values consumed by profit objects the transfer of variable activity costs to profit objects – proportionally to the performance ratio – can be carried out exactly.

Using the ABC calculation method the prime cost of a complex logistics service (or supply chain) can be elaborated in an exact way. The margins of profit objects can also be analysed by including revenues: margins show how revenues can cover production costs. Fixed cost elements are not neglected but they are taken into account mainly in the aggregated calculation levels.

If extending the scope to inter-organisational supply chains the ABC method can be used properly as it examines dynamic processes instead of static organisational units or equipment. The difference is that the planning of logistics processes will be the tasks of more market actors having independent decision competences. Thus the inter-organisational use of the proposed costing model needs a strict coordination between the involved parties.

As a summary it can be concluded that process oriented (activity based) costing can enhance efficiency evaluations in transport logistics by the following contributions:

- measuring the cost-performance ratio of logistics activities;
- measuring the prime costs and the profitability of (elementary) logistics services or their chains;
- exploring the bottlenecks or the high added-value elements within the logistics service chains.

IMPLEMENTATION ISSUES

The proposed model is able to make logistics transport costing more reliable and usable for efficiency evaluations. At the same time it has several limitations as well. For example the accuracy can not be enhanced to 100% as it would need a huge amount of resources (data collection for very detailed cost and profit object structures, comprehensive performance measurement, etc.). It is often not possible to fully harmonise the general ledger and the data requirement of the calculation model, which leads to using various interfaces. The selection of cost drivers (performance indicators) may be based – partly – on subjective decisions as the application of supporting mathematical methods (e.g. regression analyses) is not always possible. Some cost drivers can not be measured exactly: here estimations need to be used instead of accurate figures. And at last but not least, the classification of cost items as direct/indirect or variable/fix ones may also be complicated.

To overcome the problems mentioned and to build an applicable costing model some conditions influencing the success of the implementation shall also be considered. Applying activity based costing to inter-organisational supply chains requires a high level standardisation of data models, cost and performance definitions and accounting methods. Otherwise it will not be possible to implement the integrated management tool and the corresponding information system. Another prerequisite is to define the model elements (i.e. cost and profit objects) correctly so that the operation of the examined logistics service system can be modelled effectively. Input data (costs, performances, revenues) shall be made available at acceptable data quality and they have to be updated regularly. Thus the automation of data gathering and processing procedures is envisaged – as far as it is possible.

CONCLUSIONS

Reviewing numerous projects in the field of freight transport and transport logistics we have found that the application of telematics, the dissemination of information and improvement of management, the intermodality, the invention of new techniques and technologies and the presence of sustainability are the main areas around which the majority of efficiency boosting projects cluster. After defining efficiency data envelopment analysis – as a possible tool of efficiency evaluations – has been presented and shown how it can be applied to transport logistics. Finally, activity based costing, as a more effective costing method that can contribute to overall efficiency, is also presented. The practical implementation of DEA and ABC is also outlined with the view of future application. The authors intend to continue this research work with the practical use of DEA as well as ABC.

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