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Benchmarking distribution centres using Principal Component Analysis and Data Envelopment Analysis: A case study of Serbia

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ABSTRACT

The efficiency of distribution systems is largely affected by the performances of distribution centres. The main objective of this paper is to develop and propose a DEA model for distribution centres efficiency measuring that can help managers in decision making and improving the efficiency. Due to numerous indicators that describe DCs operating, the main problem is indicators selection. In order to improve discriminatory power of classical DEA models PCA–DEA approach is used. This paper analysis the efficiency of distribution centres of one trading company in Serbia. Proposed models integrate operational, quality, energy, utilisation and equipment warehouse and transport indicators. Several hypotheses are tested in this paper. The results showed that small distribution centres are more efficient than large.

1. Introduction

In order to survive in the market and achieve profitability, the companies need to perform their activities in an efficient way. Efficiency is a very important indicator of companies' operations analysis, and it is one of the basic and the most frequently used performances. Measuring, monitoring and improving efficiency are the main tasks for companies in the 21st century. The importance of efficiency measuring in logistics has been recognised in literature (Chow, Heaver, & Henriksson, 1994; Hackman, Frazelle, Griffin, Griffin, & Vlasta, 2001; Min & Joo, 2006). This process is a very complicated one due to the complex structure of logistics systems. Distribution centres (DCs) are complex logistics systems which connect producers with other participants in the chain, including end-users. DCs of trading companies and DCs in general represent complex logistics systems with a very important place and role in the supply chains. In literature little has been done for the performance measurement of the distribution side of the supply chain. This paper analyses in more detail the efficiency of DCs of the trading company that operates in the region of Serbia.

"Single ratio" indicators have been used for estimating the efficiency of DCs for a long time. These indicators do not provide enough information about the system operating. Recently, an increasing number of authors have advocated the use of approaches such as the Data Envelopment Analysis (DEA) method (Min & Joo, 2006; Toloo & Nalchigar, 2011). Adler and Golany (2001), Adler and Golany (2002) have suggested using the Principal Component Analysis (PCA), a methodology that produces uncorrelated linear combinations of original inputs and outputs, to improve discrimination in the DEA with a minimal loss of information. The DEA models often fail when there are an excessive number of inputs and outputs in relation to the number of decision making units (DMUs).

DC's operating describes a large number of different indicators, and the problem is how to select relevant indicators which describe DC operating in the best way. Variables selection problem is recognized in literature (Boussofiane, Dyson, & Thanassoulis, 1991). Various indicators with different effect on systems, subsystems, processes and activities further complicate the selection of variables. The main objective of this paper is to develop a model for measuring efficiency of DCs of one trading company. Information obtained from the company management and the author's experience is used in the process of model development.

Next section gives a review of indicators used for measuring efficiency in logistics. The third section describes the PCA–DEA approach. Efficiency evaluation system of observed DCs is given in the fourth section. In section five the results of the proposed model are described. Several hypotheses are also tested in section five. At the end of the paper, the concluding remarks and directions of future research are presented.

2. Literature review

In the field of logistics, the DEA method is mostly used for efficiency estimation. Different indicators are used for measuring efficiency in logistics (Table 1). Ross and Droge (2002) analyzed 102 DCs efficiency, as a part of complex supply chains. They also

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Table 1
Efficiency indicators in warehouses and DCs.

Publication	Input	Output	Field	Indicator types
Chakraborty, Majumder, and Sarkar (2011)	Number of employees, general expenses, space, inventory	Fill rate, sale, service time	DCs	Operational, financial, quality
Hackman et al. (2001)	Labor, space, material handling and storage equipment	The picking/shipping workload is driven by the number of orders and the number of lines on those orders, Investments in material handling equipment, The storage output index	Warehouses and DCs	Equipment, operational
Hamdan and Rogers (2008)	Labor hours, Warehouse space, technology investment, Materials handling equipment (MHE)	Throughput, order fill, space utilisation	Warehouses and DCs	Operational, quality, utilisation
Korpela et al. (2007)	Direct costs, indirect costs	Reliability (time, quality, quantity), Flexibility (Urgent deliveries, frequency, special request, Capacity (ability to respond to changes in warehousing capacity needs of a customer)	Warehouses	Quality, financial
de Koster and Balk (2008)	Number of direct full-time equivalents, Size of the warehouse, degree of automation, number of different SKUs	Number of daily order lines picked, The level of value-added logistics (VAL) activities carried out, Number of special processes, Percentage of failure-free orders	Warehouses	Operational, quality
Min and Joo (2006)	Account receivables, Salaries and wages, Expenses other than salaries and wages.	Operating income	Warehouses and DCs	Financial
Ross and Droge (2002)	Average labor experience, fleet size, equipment, mean order throughput time (MOT)	Product sales volume	DCs	Equipment (Capacity), Operational

analyzed efficiency change in time. Hamdan and Rogers (2008) used the DEA method for estimating efficiency of 3PL providers with an emphasis on warehouse operations. The authors compared the results of two DEA models with and without weight restrictions. Hackman et al. (2001) developed a model with multiple inputs and outputs to evaluate the efficiency of 57 warehouse and distribution facilities. Among other things, they confirmed conclusions concerning the relation between warehouse size, level of technology and efficiency. They used labour, space, material handling and warehouse equipment inputs, as well as movement, accumulation and storage outputs. De Koster and Balk (2008) benchmarked international warehouse operator's performances. They used equipment and capacity indicators (size of the warehouse in square meters; degree of automation, etc.), operational (number of daily order lines picked, the level of value-added logistics (VAL) activities) and quality indicators (the percentage of failure-free orders shipped; order flexibility) for efficiency evaluation.

Korpela, Lehmusvaara, and Nisonen (2007) advocated the use of cost indicators as inputs, but also qualitative indicators as outputs. The authors combined the Analytic Hierarchy Process (AHP) and the DEA model to evaluate the warehouse providers. Min and Joo (2006) measured the efficiency of third party logistics providers.

The distribution of goods today relies heavily on the use of road transport (Table 2). In literature there are different approaches for freight transport performance measurement. In the literature a variety of indicators of transport system are used. Kim (2010) has evaluated technical and scale efficiency of individual trucks in logistics. The DEA model for 62 trucks efficiency evaluation is specified with three output categories and five costs categories which represent inputs. Cruijssen, Dullaert, and Joro (2010) analysed freight transportation efficiency in Flanders. Simons, Mason, and Gardner (2004) defined Overall Vehicle Effectiveness (OVE) and state that transport efficiency is important at an economic, social and environmental level. The authors defined five transport losses or wastes: driver breaks, excess loading time, fill loss, speed loss and quality delay. McKinnon (1999) analyses KPIs for the food supply chain. They analysed vehicle utilisation and energy efficiency. They used several indicators such as the degree of empty running, fuel efficiency and deviations from schedule, time utilisation and vehicle utilisation.

Nowadays, energy efficiency has become a critical issue for logistics systems. In a situation of increasing global energy demands and rising energy costs, conserving energy is becoming a very important issue (Table 2). In literature there are many papers that investigate indicators of energy efficiency in logistics systems. Kalenoja, Kallionpää, and Jarkko Rantala (2011) studied indicators of energy efficiency of supply chains. Authors also noted the importance of some indicators like: energy consumption, water and electricity consumption, fuel consumption and material use, habitat improvements and damage due to enterprise operations, quantity of non-product output returned to process or market by recycling or reuse. The authors also link energy efficiency in supply chains with the requirements of ISO 14301 classical (environmental performance evaluation). Neto, Walther, Bloemhof, van Nunen, and Spengler (2009) recognized the problem of balancing environmental and business concerns. A detailed overview of indicators for green supply chain management is given in the paper of Hervani, Helms, and Sarkis (2005). They give the list of environmental performance metrics ranging from air emissions to energy recovery and recycling.

Mckinnon, Cullinane, Browne, and Whiteing (2010) in framework of assessment for developing sustainability in warehousing distinguished a micro and a macro-level perspective. Micro level includes business and economy with indicators of energy, water and buildings, while macro level includes environment and society with indicators of ecology, environment and land use. Kuosmanen