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A framework for measuring transport efficiency in distribution centers

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ABSTRACT

Performances of distribution systems are largely affected by the performances of transport systems. This paper is devoted to the analysis of the efficiency of transport subsystems in distribution centers. Transport is a logistics process with the highest energy consumption. In the transport systems two aspects of measuring efficiency are identified. The first aspect is the fleet efficiency which is related to the higher level of decision making. The second aspect of decision making is the vehicle efficiency as operational level of decision making. The main objective of this paper is to propose models for measuring transport efficiency, as well as to identify main factors that affect transport efficiency. The proposed models are based on Principal Component Analysis and Data Envelopment Analysis approaches. According to the results fleet management system, catchment area, vehicle capacity, the age of vehicles and manufacturers are the basic factors that affect transport efficiency.

1. Introduction

Due to a dynamic market and environmental changes, the distribution centers have to realize their activities and processes in an efficient way. During the last three decades logistics has been recognized as one of the most important service industries. Logistics has a crucial role in supply chains, which reflects in connecting members into supply chains. Distribution centers (DCs) are complex logistics systems which connect producers with other participants in the chain, including end-users. Two basic subsystems of DCs are warehouse and transport subsystems. The most important part of transport subsystem refers to fleet and vehicle operating.

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 and importance of effectiveness measuring have been recognized in literature (Chow et al., 1994; Adler and Berechman, 2001; Hackman et al., 2001). “Single ratio” indicators have been used for estimating the efficiency of logistics systems for a long time. These indicators do not provide enough information about the system operating. Numerous authors have advocated the use of approaches such as the Data Envelopment Analysis (DEA) method (Min and Joo, 2006). On the other side, Adler and Golany (2001, 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. When there are an excessive number of inputs and outputs in relation to the number of decision making units (DMUs), DEA method is inapplicable.

The main object of this paper is to propose a model for measuring transport efficiency on different levels, as well as to identify the key factors that affect transport efficiency. To the best of our knowledge there were no papers that simultaneously evaluate the transport efficiency on the described levels and investigate factors that affect transport efficiency. The research is conducted on the DCs that operate in Serbia. Two measurement levels (aspects) are identified in this paper. The first level relates to measuring efficiency of fleets, while the second relates to vehicle efficiency. The information obtained from the company management is used in the process of the model development. The examination of the company management, fleet size, gravity area (catchment area – the area that DC serves), the age of vehicle, vehicle capacity, vehicle manufacturer, influence on the efficiency scores are also objective of this paper.

This paper consists of six sections. Section 2 gives a review of the transport efficiency measuring in the literature. Hypotheses are also defined in the next section. Transport efficiency measuring aspects are described in Section 3. The models for evaluating transport and the vehicle efficiency are also proposed in this section. The results of efficiency measurement are given in Section 4. Examination of the factor influence on the efficiency scores and

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hypotheses testing are realized in Section 5. The overall conclusions and future directions are presented in Section 6.

2. Literature review and hypotheses definition

Road transport has dominant role in the distribution of goods. Importance of transportation and vehicle fleet management is recognized in the literature (Pedraza-Martinez and Van Wassenhove, 2012). There are different approaches for freight transport performance measurement in the literature (Table 1).

Kim (2010) has evaluated technical and scale efficiency of the 62 individual trucks in logistics. The DEA model for efficiency evaluation is specified with three output categories and five costs categories which represent the input. Cruijssen et al. (2010) analyzed efficiency of the freight transportation in Flanders. Simons et al. (2004) defined the Overall Vehicle Effectiveness (OVE). They also stated that transport efficiency is important at an economic, social and environmental level. The authors defined five transport losses or waste: driver breaks, excess loading time, fill loss, speed loss and quality delay. Mckinnon (1999) analyzed KPIs for the food supply chain with special emphasis on the degree of empty running, fuel efficiency, deviations from schedule, time utilization and vehicle utilization. Donselaar et al. (1998) investigated transport and distribution effectiveness.

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. There are many papers that investigate indicators of energy efficiency in transport and logistics in general. Kalenoja et al. (2011) studied indicators of energy efficiency of supply chains, with emphasis on 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. They also analyzed the requirements of ISO 14301 standard (environmental performance evaluation) in the context of energy efficiency. Neto et al. (2009) recognized the problem of balancing environmental and business concerns. A comprehensive overview of environmental performance metrics for the green supply chain, that range from air emissions to energy recovery and recycling, is given in the paper of Hervani et al. (2005). The main environmental pressures and undesirable outputs in road transport are defined by Kuosmanen and Kortelainen (2005). The authors also emphasized the importance of economic variables such as mileage and fuel consumption. Sarkis and Talluri (2004) analyzed eco-efficiency using qualitative and quantitative inputs and outputs. Chow et al. (1994) examined the definition and measurement of performance in logistics research. The authors defined “distribution effectiveness” as adequacy, consistency, accuracy, timeliness, initiative, responsiveness.

Numerous factors affect transport efficiency. These factors are not sufficiently investigated in the literature. The situation is no better in practice. In this paper several factors are categorized according to two efficiency measurement levels. Three factors are identified for each level. Fleet management, fleet size and gravity area are basic factors that affect fleet efficiency. On the operational level vehicle efficiency is influenced by the age of vehicle, vehicle capacity and vehicle manufacturer.

In the first hypothesis it is assumed that information system (*Fleet Management System-FMS*) affects fleet efficiency. In that sense the first hypothesis investigates the difference of the fleet efficiency scores between two analyzed companies (company A and company B) with different fleet management systems. Because of the importance and differences in each fleet management systems we predict differences in the efficiency scores in different companies. The first hypothesis has the following form:

H1. : There is a difference in fleet efficiencies of company A and company B caused by the fleet management system.

Many past studies analyzed relationship between size of logistics systems and efficiency. (Hackman et al., 2001; Banaszewska et al., 2012). However, the aforementioned papers analyzed warehouses and distribution centers. Because of the previous literature we assume that fleet size affects efficiency scores since of economies of scale. In that manner the next hypothesis is set:

Table 1
Review of transport efficiency measuring.

Publication	*Indicators*	*Field*	*Indicator types*
Andrejić et al. (2013)	Vehicles, Forklifts, Fuel, Electricity consumption, Invoices (Demands), Warehouse overtime, Time truck utilization, Failures in warehouse, Failures in transport, Write off expired goods	Transport and distribution	Operational, Financial, Quality, Utilization
Cruijssen et al. (2010)	Equipment (e.g. number of trucks, number of trailers, total loading capacity etc.), Labor (e.g. total wages, (drivers'), total hours worked, number of employees, etc.), Added value, Profit, Intangible assets (market information, customer contacts, goodwill etc)	Transport systems and vehicles	Equipment (Capacity), Operational, Financial, Energy
Donselaar et al. (1998)	Costs, Wages, Hours/truck, Hours/driver, Speed, Turnover/trip,(un)loading time/trip, Turnover, Load factor, Loading capacity, Percentage km driven empty, Turnover/truck, Number of trucks	Transport and distribution	Equipment (Capacity), Operational, Financial
Hervani et al. (2005)	Total energy use, fugitive non-point air emissions, total electricity use, total fuel use, other energy use, major environmental, social, and economic impacts associated with the life cycle of products and services Strategic, tactical and operational measurement levels	Transport	Energy, Environmental
Mckinnon (1999)	Vehicle space utilization, Vehicle time utilization, Empty running, Deviations from schedule, Fuel consumption	Transport systems and vehicles	Energy, Utilization
Neto et al. (2009)	Masses entering the treatment system, Output masses that are recycled	Logistics network	Environmental
Kalenoja et al. (2011)	Quality, Time, Costs, and Flexibility, Environmental indicators such as energy consumption or carbon dioxide emissions, ISO 14031 performances (environmental condition indicators, management performance indicators and operational performance indicators)	Transport	Financial, Energy, Quality, Environmental
Kim (2010)	Fuel cost, Oil cost, Supplies cost, Labor cost, Tax, Insurance, Transportation distance, Transportation amount	Transport systems and vehicles	Financial, Operational, Energy
Kuosmanen and Kortelainen (2005)	Mileage, Fuel consumption, Undesirable outputs (CO_2, CH_4,N_2O, CO, NO_x SO_2, emissions…)	Transport systems and vehicles	Operational, Energy, Environmental
Sarkis and Talluri (2004)	Qualitative inputs (managerial plans, Green Purchasing program, ISP 14000…) Quantitative inputs (raw material intake, energy, materials used, employees…) Qualitative outputs (biodiversity impacts, greenhouse impact, community response…) Quantitative outputs (water emissions, air emissions, solid wastes, products, penalties…)	General organization	Environmental, Qualitative, Operational
Simons et al. (2004)	Labor, Energy consumption, Operating costs, Vehicle emissions, Fuel,, Transport losses or wastes (driver breaks, excess loading time, fill loss, speed loss, quality delay)	Transport systems and vehicles	Financial, Operational, Energy, Quality